NONRESTORATIVE SLEEP IN HEALTHY ADULTS

WITHOUT INSOMNIA: ASSOCIATIONS WITH

EXECUTIVE FUNCTIONING, FATIGUE,

AND PRESLEEP AROUSAL

by

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ABSTRACT

Previous research suggests that nonrestorative sleep (NRS) in the absence of insomnia symptoms or other sleep disorders is associated with daytime dysfunction. This study examined the association between NRS and daytime dysfunction in a healthy adult sample (n = 79, 68 % female, mean age = 27.5, SD = 6.5) without insomnia or other sleep disorders using a multiday assessment approach. Daytime dysfunction measures included behavioral assessment of executive functioning (EF) and self-report of perceived EF difficulties, past-month sleep-related dysfunction, and experience-sampled affect ratings, including fatigue. Additionally, the association between NRS and presleep arousal, a vulnerability factor for insomnia, was examined; daytime dysfunction was examined as a mediator of this association. NRS was significantly associated with poorer performance on a behavioral measure of EF, perceived EF difficulties, daily ratings of fatigue, and past-month reported daytime dysfunction--associations remained after controlling for age and sleep duration (measured by actigraphy). The association between NRS and presleep arousal was explained by perceived EF difficulties. Findings suggest that NRS in the absence of other insomnia symptoms is associated with poorer cognitive functioning and may be a vulnerability factor for the development of insomnia.

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INTRODUCTION

Nonrestorative sleep (NRS) refers to the subjective experience of feeling unrefreshed upon awakening that is not attributed to lack of sleep (Stone, Taylor, McCrae, Kalsekar, & Lichstein, 2008). NRS is sometimes considered a core symptom of insomnia (Vernon, Dugar, Revicki, Treglia, & Buysee, 2010) and it is a common complaint of patients with chronic fatigue syndrome, fibromyalgia, and organic sleep disorders such as sleep apnea (American Sleep Disorders Association, 2005; Moldofsky, 1997; Moldofsky & MacFarlane, 2005). Importantly, prior studies indicate that NRS can occur *in the absence of* other insomnia symptoms and is associated with daytime dysfunction (Ohayon, Riemann, Morin, & Reynolds III, 2012; Roth et al., 2010; Sarsour et al. 2010; Zhang et al., 2013). However, more research is needed to determine whether NRS without insomnia symptoms is a distinct construct with similar or worse daytime functioning consequences as individuals with insomnia symptoms (difficulties initiating or maintaining sleep) (Stone, Taylor, McCrae, Kalsekar, & Lichstein, 2008; Wilkinson & Shapiro, 2012). The goal of the present study was to investigate the extent to which daytime dysfunction is associated with NRS in individuals who do not have insomnia or other sleep disorders using a multiday assessment approach. Specifically, associations between NRS and both perceived and objective cognitive functioning difficulties were examined with a particular focus on executive functioning (EF). In addition, daily affect and fatigue ratings were examined as evidence of daytime dysfunction. Furthermore, we explored whether NRS is associated with presleep cognitive and somatic arousal, a vulnerability factor for the development of insomnia (Bonnet & Arand, 2010; Fernandez-Mendoza et al., 2010; Riemann et al., 2010).

Nonrestorative Sleep

Nonrestorative sleep refers to the subjective experience of feeling unrefreshed upon awakening that is not attributed to lack of sleep or other sleep disorders (e.g., obstructive sleep apnea) (Stone, Taylor, McCrae, Kalsekar, & Lichstein, 2008; Wilkinson & Shapiro, 2012). Epidemiological studies indicate that the prevalence of NRS in the general population ranges from 1.4 to 35% (Ohayon, 2005; Ohayon, 2009; Ohayon & Bader, 2010; Ohayon & Hong, 2002; Ohayon & Partinen, 2002; Ohayon & Sagales, 2010; Ohayon, Roberts, Zulley, Smirne, & Priest, 2000; Ohayon & Roth, 2001; Roberts, Roberts, & Chen, 2002; Roth et al., 2006; Sarsour et al., 2010). NRS is also related to psychopathology. Previous epidemiological research indicated that NRS sleep (without insomnia symptoms) is associated with mental health problems, including anxiety and depressive disorders (Ohayon, 2005; Ohayon & Roth, 2001). Furthermore, in a longitudinal study, NRS predicted mental health problems (Zhang, Lam, Li, & Wing, 2012). Thus, even without other symptoms of insomnia, NRS appears to have significant mental health consequences.

Within the sleep literature, heterogeneous operationalization of NRS across studies has made it difficult to make definitive conclusions about the role NRS plays in sleep disorders and other health problems (Stone, Taylor, McCrae, Kalsekar, & Lichstein, 2008). In general, NRS may result from any number of disorders and there are no clear mechanisms that explain the association between mental and physical health disorders and NRS. Thus, it has been suggested that the conceptualization of NRS should mirror the approach used for insomnia, in which NRS could result from medical or psychiatric conditions, but may also exist as a stand-alone disorder (see Wilkinson & Shapiro, 2012 for review). Assessment of NRS will continue to rely on self-report, in part because subjective perception is central to the construct, but also because no objective tools reliably identify NRS (Stone et al., 2008). In the only study to have analyzed polysomnographic data between NRS-only participants and healthy controls, the only differences observed were that NRS-only individuals demonstrated less time in sleep stages 3 and 4 (specifically in the first hour of the night) and REM sleep; yet these differences were minimal (Roth et al., 2010). Until the recently published Restorative Sleep Questionnaire (Drake et al., 2014), no self-reported inventory was available to specifically measure NRS, with most studies utilizing components of existing inventories or morning sleep diaries.

Importantly, it has also been suggested that the inclusion of NRS as a primary symptom of insomnia is problematic given that it is commonly associated with other conditions such as anxiety and depressive disorders, fibromyalgia, and chronic fatigue syndrome (Stone, Taylor, McCrae, Kalsekar, & Lichstein, 2008). Thus, future research is needed to investigate the association between NRS and daytime dysfunction in populations that do not meet criteria for conditions in which NRS is a common complaint.

NRS and Daytime Dysfunction

There is growing evidence that NRS is associated with daytime impairment even in the absence of other disorders. Specifically, research indicates that people with NRS, without other insomnia symptoms, evidence similar or stronger daytime impairment than people with other sleep or health problems. Studies comparing participants with NRS without insomnia symptoms and healthy controls found that individuals endorsing NRS reported more daytime impairment, including fatigue, sleepiness, and low work productivity (Ohayon, 2005; Roth et al., 2010). Furthermore, there is evidence that NRS without insomnia symptoms is associated with reported cognitive difficulties (Ohayon, Riemann, Morin, & Reynolds III, 2012: Sarsour et al., 2010). However, another study found that participants with NRS (without other insomnia symptoms), were less likely to report daytime impairment than participants with NRS in combination with and other insomnia symptoms (Ohayon & Roth, 2001).

Previous research has also found an association between NRS and daytime dysfunction related to affect. Ohayon, Riemann, Morin, and Reynolds III (2012) found that individuals with NRS without insomnia symptoms reported affective difficulties (depression, anxiety, irritability). The association between NRS and affect is unclear as few studies have investigated this relationship. Additional research is needed to fully characterize the association between NRS and affect; in particular, examination of daily ratings of affect may better characterize the association.

Importantly, more research is needed to understand associations with cognitive functioning among people reporting NRS without other sleep difficulties. In particular, executive functioning (EF) may be associated with NRS. EF refers to a set of higher-order neurocognitive processes that allow one to generate novel plans that are purposeful and goal-directed (Suchy, 2009, 2016). Executive functioning is measured through behavioral performance assessments, as well as self-report inventories. Self-report EF inventories assess perceived difficulties in executive functions in real-world settings. In general, the perception of EF (i.e., self-reported) and behavioral assessment of EF are related, but distinct, constructs. For example, Suchy and colleagues (2016) found that both perceived EF and performance on a behavioral measure of EF were associated with glycemic control among older adolescents (performance on the behavioral measure of EF was no longer significantly associated with glycemic control when taking IQ into consideration). Thus, there may be utility in examining both self-reported and behavioral assessments of EF in characterizing daytime dysfunction related to NRS.

Taken together, previous research provides converging evidence that NRS without other insomnia symptoms is strongly associated with daytime dysfunction (i.e., cognitive, physical, affective, and emotional functioning). However, additional research is needed to better understand these associations given prior limitations of studies. For example, prior studies investigating the association between NRS and daytime dysfunction have mostly relied on single item assessments of daytime dysfunction that have been assessed concurrently with NRS. These studies do not allow for the investigation of whether NRS assessed upon awakening may set the stage for daytime dysfunction in daily life. Furthermore, objective measures of cognitive functioning and the use of daytime functioning measures with higher reliability would better explicate these associations.

Presleep Arousal

The Spielman three-factor model provides an overall framework for the development and maintenance of insomnia (Bootzin & Epstein, 2011; Spielman,1986; Spielman & Glovinsky, 1991). In this model, predisposing and precipitating factors are hypothesized to lead to acute insomnia that may become chronic with the emergence of perpetuating factors. Specifically, hyperarousal, referring to chronic physiological arousal, is believed to play a critical role in the development and maintenance of insomnia (Bonnet & Arand, 2010; Morin, 2003; Riemann et al., 2010), which is purported to be preceded by increased stress-reactivity (Harvey, Gehrman, & Espie, 2014). In addition, cognitive arousal prior to bedtime is common among people with insomnia (Harvey, 2000; Lichstein & Rosenthal, 1980; Morin, Rodrigue, & Ivers, 2003; Nicassio, Medlowitz, Fusel, & Petras, 1985; Robertson, Bloomfield, & Espie, 2007). Indeed, Fernandez-Mendoza and colleagues (2010) found that presleep cognitive arousal is a vulnerability factor for the development of insomnia. In related research, Nofzinger et al. (2004) found that in comparison to good sleepers, individuals with insomnia demonstrated higher global cerebral glucose metabolism when transitioning from awake to sleep states. Specifically, they found that prior to sleep, individuals with insomnia relative to good sleepers displayed a smaller metabolism decrease in brain regions that promote wakefulness, including regions implicated in EF (e.g., prefrontal cortex). Furthermore, individuals with insomnia demonstrated reduced prefrontal cortex activation upon awakening. Thus, it was concluded that daytime fatigue experienced by individuals with insomnia may reflect reduced prefrontal cortex activation.

Taken together, prior research suggests that presleep arousal is a risk factor for the development of insomnia. It is unknown whether NRS is associated with presleep arousal among individuals who do not meet criteria for insomnia. In addition, reduced prefrontal cortex activation may be important in next-day perceptions of NRS. In fact, it is possible that perceptions of poor restoration upon awakening may reflect reduced prefrontal cortex activation. Given the documented associations between NRS and daytime dysfunction and the deleterious effect of reduced prefrontal cortex activation due to presleep arousal may have on daytime functioning, it is possible that daytime dysfunction may mediate the association between NRS and presleep arousal. This would suggest a vicious cycle of NRS that leads to daytime dysfunction that sets the stage for presleep arousal and further vulnerability to nonrestorative sleep.

Current Study

The purpose of the present study was to examine the association between NRS and daytime dysfunction (cognitive functioning, daily affect, and fatigue ratings) in an experience-sampling study of 79 healthy adults without sleep disorders. It was predicted that NRS would be associated with daytime dysfunction, operationalized as past-month rating of sleep-related daytime dysfunction, experience-sampled affect and fatigue ratings, as well as performance on a behavioral measure of EF and perceived EF difficulties. Specifically, NRS was hypothesized to be positively associated with negative valence/low arousal affect, in particular ratings of fatigue. In addition, the association between NRS and presleep cognitive and somatic arousal was examined, with the prediction that NRS would be positively associated with presleep arousal and that this relationship would be mediated by daytime dysfunction. Hypothesized associations were initially examined with zero-order correlations and then in regression controlling for age and sleep duration (other factors associated with daytime dysfunction and cognitive functioning.

METHOD

Participants

Participants were 79 healthy adults (32% male; mean age = 27 years, *SD* = 6.5) recruited from the University of Utah participant pool and the greater Salt Lake City community. The racial composition was 91% Caucasian, 5% Asian Pacific, and 4% unspecified. Exclusionary criteria included primary language other than English; age beyond 20-45 years; clinical insomnia symptoms, obstructive sleep apnea; left hand dominant; arm impairments that could interfere with cognitive task performance; visual impairments that could interfere with reading or computerized tasks; current use of tobacco; current pregnancy; history of renal failure, pulmonary disorder, hypertension, major orthopedic surgery, Multiple Sclerosis, heart surgery, brain surgery, brain tumor, stroke or aneurysm, seizures, brain trauma, and brain trauma; and current use of neuroleptic, cardiovascular, or hypnotic medications.

Procedures

Participants completed a 4-day protocol. On Day 1, after completing informed consent, participants completed a laboratory assessment that included standardized behavioral testing of EF, self-reported sleep disturbances in the previous month, and depressive symptoms in the prior 2 weeks. On Day 2, participants completed affective ratings throughout the day via palm-pilot. On Days 2-3, participants completed nighttime ratings of presleep arousal and EF disturbances for that day, and morning ratings of nonrestorative sleep. On Days 1-3 participants wore wrist actigraphy. On Day 4, participants completed final morning ratings of sleep restoration, underwent debriefing, and were given compensation.

Measures

Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). The PSQI is a self-report measure that assesses sleep quality and disturbances during the previous month. The scale consists of 19 items that are used to derive seven component scores: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. A global score is obtained by adding all seven component scores together, with higher scores indicating poorer sleep quality; however, the item-level daytime dysfunction subscale was the primary focus of the current study.

Beck Depression Inventory-II **(**BDI; Beck, Steer, & Brown, 1996). Participants completed the BDI-II, a self-report inventory of depressive symptoms experienced over the past 2 weeks. It consists of 21 items, on a scale from 0 to 3, with higher scores indicating greater depression severity. The BDI-II shows high internal consistency (Beck, Steer, Ball, & Ranieri, 1996) and test-retest reliability (Beck et al., 1996). The total BDI score was used in analyses. In this study, Cronbach's alpha for the BDI was .89.

Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001). Four subtests were administered from the D-KEFS from which eight conditions reflecting central components of EF were used to create an EF composite. The subtests and their components used to create the EF composite were Trail Making (Letter Number Sequencing completion time), Verbal Fluency (Letter and Category correct responses), Design Fluency (number of correct responses for three conditions), and Color-Word Interference (Inhibition and Inhibition/Switching completion times). Age-corrected scaled scores were calculated for each subtest and all eight conditions were averaged to create an EF composite. Overall, these eight components assess working memory, set-maintenance, inhibition, cognitive control, initiation, and generative fluency.

Importantly, cognitive functions are organized hierarchically, with higher-order processes like EF relying on lower-order processes (Stuss, Picton, & Alexander, 2001). To control for non-EF aspects of the composite, we first created a lower-order processes composite by averaging the age-correct scores of six conditions including Color Naming and Word Reading from the Color-Word Interference Test, Visual Scanning, Number Sequencing, Letter Sequencing, and Motor Speed from the Trail Making Test. Next, we controlled for the lower-order processes by removing their variance from the EF composite, resulting in an unstandardized residual of the EF composite, reflecting EF without confounding lower-order processes. The unstandardized residual of the EF composite was used in all subsequent analyses.

<u>Perceived EF difficulties</u>. At the end of Days 2 and 3, participants were asked to complete a questionnaire assessing difficulties in executive functioning experienced throughout the day. Nine items, rated on a 5-point Likert scare ranging from 0 (not at all) to 4 (constantly), were selected from self-report measures of EF, including the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy, & Kenworthy, 2000) and the Conners' Adult ADHD Rating Scales (CAARS; Conners, Erhardt, &

Sparrow, 1996). These items were used to assess subjective difficulties in the following domains: 1) *emotion regulation* (e.g., "Thinking about today only, to what extent did you get upset or angered over little things"); 2) *behavioral regulation* (e.g., "Thinking about today only, to what extent did you say or do things without thinking"); and 3) *cognitive difficulties* (e.g., "Thinking about today only, to what extent did you have difficulty concentrating on or completing tasks"). Cronbach's alpha for Day 1 and 2 for the total perceived difficulties in EF ratings were .63 and .80. Perceived difficulties in EF for Day 1 and 2 were averaged and used in the analyses. Cronbach's alphas for average scores were .83 for total perceived EF difficulties, .76 for emotion regulation, .78 for cognitive difficulties, and .63 for behavioral regulation.

Affective ratings. Sixteen emotional descriptors were used to assess a wide range of affective states from the affective circumplex (Russell, 1980), including positive valence/high arousal (i.e., *excited, elated, alert, happy*), positive valence/low arousal (i.e., *relaxed, calm, serene, contented*), negative valence/high arousal (i.e., *stressed, tense, upset, nervous*), and negative valence/low arousal (i.e., *sad, lethargic, depressed, fatigued*). Each affective rating contained the same stem question (e.g., "How FATIGUED do you feel right now?") and was rated on a 5-point Likert scale from 1 (not at all) to 5 (very much). Participants were prompted to respond to a total of 14 prompts throughout each day. The order of the affect items was randomized for each prompt in order to reduce overlearned and careless responding. An average score for each of the 16 affective ratings was calculated. Average score ratings for each affect item were then used to calculate summary scores for positive valence/high arousal, positive valence/low arousal, negative valence/high arousal, and negative valence/low arousal scores.

Cronbach's alphas for the affective summary scores were .57 for positive valence/high arousal, .81 for positive valence/low arousal, .94 for negative valence/high arousal, and .89 for negative valence/low arousal. Given prior associations between NRS and fatigue, average ratings for this item were also examined separately.

Presleep Arousal Scale (PSAS; Nicassio, Medlowitz, Fussel, & Petras, 1985). Participants rated levels of cognitive and somatic presleep arousal before going to bed each night. The PSAS is a self-report measured comprised of 16 items rated from 1 (not at all) to 5 (extremely) that assess cognitive (e.g., worry related to sleep, inability to shut off thoughts, depressing or anxious thoughts) and somatic (e.g., upset stomach, racing heart, shortness of breath) arousal states at bedtime. A total score was obtained by adding all items together, with higher scores indicating greater presleep arousal. Higher scores on the PSAS reliably differentiate between normal sleepers and patients with clinical insomnia (Morin & Espie, 2003; Robertson, Broomfield, & Espie, 2007). Average of PSAS scores were calculated and used in the analyses. Cronbach's alphas for average scores were .89 for PSAS, .88 for the presleep cognitive arousal scale, and .71 for the presleep somatic scale.

Actigraphy. Participants wore wrist actigraphy (Actigraph GT1M, The Actigraph, Pensacola, Florida) continuously during Days 1-3. The standard medium-sensitivity scoring algorithm from the Actiware 5 software was used to calculate actigraphy sleep measures. A total sleep time average score across the 3 days was calculated and used in the analyses.

Nonrestorative sleep. As part of a morning sleep diary, participants were asked *How rested or refreshed did you feel this morning?* for each of three days. The item was rated on a 4-point Likert scale ranging from 0 (very much rested/refreshed) to 4 (not at all), with higher ratings indicating greater nonrestorative sleep. An average of the three morning ratings was used for subsequent analyses. Cronbach's alpha for NRS was .59.

RESULTS

Zero Order Correlations and Descriptive Statistics

Zero-order correlations and descriptive statistics are presented in Table 1. Results indicated that NRS was significantly associated with performance on a behavioral measure of EF, perceived EF, and past-month sleep-related daytime dysfunction. Additionally, NRS was significantly associated with presleep arousal and depressive symptoms. NRS was associated with daily ratings of fatigue, but was not significantly associated with other affective ratings, including negative valence/low arousal affective ratings.

Regression Analyses

Regression analyses were used to investigate the association between NRS and performance on a behavioral measure of EF, perceived EF difficulties, fatigue, and past-month sleep-related daytime dysfunction, controlling for age and actigraphy-measured sleep duration. As presented in Table 2, NRS remained significantly associated with performance on a behavioral measure of EF, perceived EF difficulties, daily ratings of fatigue, and past-month sleep-related daytime dysfunction.

Next, we examined the association between NRS and presleep arousal. As presented in Table 1, NRS was significantly associated with presleep arousal. Subscale analyses indicated that NRS was positively associated with both presleep cognitive (*B*=

0.58, $\beta = 0.24$, $p < 0.05$) and somatic (B= 1.4, $\beta = 0.27$, $p < 0.05$) arousal. In a regression model controlling for sleep duration, NRS remained significantly associated with presleep arousal (B= 2.6, $\beta = 0.36$, $p < 0.05$) whereas sleep duration was not significantly associated with presleep arousal (B= -0.01, $\beta = -0.08$, $p > 0.05$).

Mediation Analyses

In order to assess the hypothesized indirect effect of NRS on presleep arousal through daytime dysfunction, bootstrapping mediation analyses were conducted. Correlational analyses indicated that perceived EF difficulties may be a mediator of the association between NRS and presleep arousal. As reported in Table 1, NRS, daily EF ratings, and presleep arousal were correlated with one another. Results of the bootstrapping mediation analyses revealed a pattern consistent with mediation in which perceived EF difficulties (b = 1.1, 95% BCa CI [0.34, 2.2]) mediated the relationship between NRS and presleep arousal.

Table 1.

Zero-order correlations among study variables

	1	2	3	4	5	6	7	8	9	10
1. NRS										
2. Behavioral EF	**-0.26**									
3. Perceived EF Difficulties	**0.33**	0.04								
4. Fatigue	**0.33**	-0.05	0.19							
5. PSQI- Daytime Dysfunction	**0.26**	-0.07	**0.32**	0.07						
6. Positive Valence / High Arousal	-0.24	0.12	0.08	-0.2	-0.07					
7. Positive Valence / Low Arousal	-0.11	0.07	0.03	-0.13	0.14	**0.63**				
8. Negative Valence / High Arousal	-0.03	0.21	-0.11	**0.58**	-0.07	-0.13	**-0.36**			
9. Presleep Arousal	**0.31**	-0.13	**0.53**	0.06	**0.52**	0	0.03	0.18		
10. Depression	**0.34**	0.01	**0.45**	0.13	**0.63**	-0.07	0.12	0	**0.68**	
11. Sleep-Duration	0.08	0.07	0.05	**0.27**	-0.01	0.18	0.13	0.16	-0.06	-0.5
Mean	1.8	0	5.8	3.8	1.6	3.3	3	4.2	8.1	6.9
Standard Deviation	0.8	1.4	3.4	0.9	1.4	0.5	0.6	0.9	7.9	1.2

Note: Correlations in boldface indicate $p < 0.05$.

Table 2.

Associations between NRS and daytime dysfunction, controlling for age and sleep duration (actigraphy)

	β	*t*	*p*
ΔR^2			
DV: Behavioral Measure of EF			
Age	.02	.14	>.05
Sleep Duration	.09	.71	>.05
NRS	-.29	-2.3	.02
.08			
Total R^2 = .09			
DV: Perceived EF Difficulties			
Age	.01	.08	>,05
Sleep Duration	.03	.2	>.05
NRS	.36	2.9	.01
.12			
Total R^2 = .13			
DV: Fatigue			
Age	.06	.5	>.05
Sleep Duration	.22	1.8	>.05
NRS	.42	3.5	.00
.17			
Total R^2 = .26			
DV: PSQI-Sleep-Related Daytime Dysfunction			
Age	-.13	-1.1	>.05
Sleep Duration	-.02	-.18	>.05
NRS	.3	2.4	.02
.08			
Total R^2 = .09			

DISCUSSION

The current study examined the association between NRS and daytime dysfunction in healthy adults without insomnia or other sleep disorders. Specifically, the current study examined the association between NRS and perceived EF and a behavioral measure of EF, daily affective ratings, including fatigue, as well as self-reported sleep-related daytime dysfunction in the prior month. Furthermore, the association between NRS and presleep cognitive and somatic arousal was investigated. Results indicated that NRS is associated with poor performance on a behavioral measure of EF, perceived difficulties in EF, daily ratings of fatigue, past-month sleep-related daytime dysfunction, and presleep arousal. In addition, the association between NRS and presleep arousal was explained by perceived EF difficulties, consistent with mediation.

NRS and Daytime Dysfunction

Prior studies have found that NRS is associated with reported cognitive difficulties, though the association has often been with single-item concurrent measures (Ohayon, Riemann, Morin, & Reynolds III, 2012, Sarsour et al., 2010). In the current study, NRS was associated with both perceived daily EF difficulties and performance on a behavioral measure of EF. Further, controlling for age and sleep duration, the association between NRS and performance on a behavioral measure EF and perceived difficulties in EF remained significant. This study is the first to demonstrate that morning ratings of poor restoration from sleep are associated with poorer performance on a behavioral measure of EF and perceived EF difficulties in daily life. These findings support the notion that NRS, in the absence of sleep disorders or other chronic health problems, is associated with objective cognitive functioning difficulties. Future research is needed to investigate mechanisms of the association between NRS and EF. These findings suggest that interventions to improve attentional control, such as mindfulness meditation, may mitigate NRS (Williams & Thayer, 2009).

NRS was also associated with past-month ratings of sleep-related daytime dysfunction. This finding is consistent with previous studies that showed an association between NRS and reported daytime dysfunction in populations without insomnia (Ohayon, 2005, Ohayon, Riemann, Morin, & Reynolds III, 2012; Roth et al., 2010, Sarsour et al., 2010; Zhang et al., 2013). In addition, NRS was positively associated with daily ratings of fatigue. This finding replicated previous research that showed an association between NRS and fatigue in populations without insomnia symptoms (Ohayon, 2005, Ohayon, Riemann, Morin, & Reynolds III, 2012; Roth et al., 2010). Contrary to prediction, NRS was not associated with daily affective ratings of negative valence / low arousal. Additionally, a marginally significant negative association was found between NRS and affective ratings of positive valence / high arousal, which suggests that individuals with NRS may experience lower positive affect throughout the day compared to individuals with reports of better sleep-related restoration. These findings confirm the centrality of fatigue as a daytime consequence of NRS.

NRS and Presleep Arousal

Results from the present study indicated that NRS is associated with presleep cognitive and somatic arousal. These findings suggest that NRS may be a risk factor for the development of other insomnia symptoms, given that presleep arousal is a vulnerability factor (Bonnet & Arand, 2010; Fernandez-Mendoza et al., 2010; Morin, 2003; Riemann et al., 2010). In addition, the association between NRS and presleep arousal dropped to nonsignificance when perceived EF difficulties were controlled, supporting the hypothesis that NRS may set the stage for daytime cognitive dysfunction, which, in turn, may confer vulnerability for presleep arousal. Previous studies have found that individuals with insomnia evidence high levels of presleep cognitive and somatic arousal (Harvey, 2000; Lichstein & Rosenthal, 1980; Morin, Rodrigue, & Ivers, 2003; Nicassio, Medlowitz, Fusel, & Petras, 1985; Robertson, Bloomfield, & Espie, 2007). Furthermore, research indicates that presleep arousal is a prominent heritable vulnerability for insomnia. Fernandez-Mendoza and colleagues (2014) found that parents who are vulnerable to stress-related insomnia have offspring that demonstrated cognitive-emotional arousal and poor coping skills. The current study highlights the existence of multiple vulnerability factors for presleep arousal among healthy adults that have not developed insomnia or other sleep problems. Accordingly, it may be beneficial to include assessments of sleep restoration, mood, and cognitive difficulties as potential targets for presleep arousal prevention.

Findings from the current study indicated that NRS is associated with depressive symptoms amongst individuals without insomnia, consistent with prior research indicating that NRS is associated with mental health problems (Ohayon, 2005; Ohayon &

Roth, 2001). Future research is needed to clarify how NRS and mental health problems influence one another longitudinally and whether treating one may mitigate the other (Stone, Taylor, McCrae, Kalsekar, & Lichstein, 2008). In addition, the current study found that NRS was not associated with actigraphy-assessed sleep duration. Ohayon (2005) found that shorter sleep duration was associated with a higher prevalence of NRS. However, results from a multivariate model suggested that shorter sleep duration was a protective factor for NRS and that sleep duration over 9 hours was a risk factor for NRS. Ohayon (2005) concluded that the relationship between short sleep duration and NRS was explained by other factors.

Limitations and Future Directions

The current study strengths include the use of a well-validated behavioral assessment of EF, experience-sampling assessment of affect including fatigue, use of actigraphy to assess sleep duration, and screening for insomnia and sleep apnea that permitted investigation of "pure" NRS in a healthy sample. However, a number of limitations should be considered. The sample size is modest and participants were mostly young and Caucasian; generalization to other age and ethnic groups should be made cautiously. Additionally, associations between NRS, daytime dysfunction, and presleep arousal are based on summary scores across days, precluding the ability to make strong inferences about causal direction. Also, the behavioral measure of EF was assessed only once and therefore indexed both "trait" and "state" EF. Thus, conclusions about the association between the behavioral measure of EF and NRS should be made with caution and speak to the importance of future research that includes multiple assessments of both constructs. Furthermore, Stone et al., (2008) recommended that individuals should be labeled as having NRS only if they report feelings of poor restoration in the morning three times per week for a month. Although these recommendations have been deemed arbitrary by other researchers (Wilkinson & Shapiro, 2012), it is the case that the current study offers only a "snapshot" of NRS and daytime dysfunction correlates in daily life.

The findings of the current study provide support for the notion that NRS is associated with daytime dysfunction in the absence of insomnia or other sleep problems. The conceptualization of NRS is in its early stages and additional research is needed to understand biological mechanisms that account for the associations between NRS and mental and physical health problems. For example, recent research indicates that inflammation may be an important biological correlate of NRS (Zhang et al., 2013). Wilkinson and Shapiro (2012) posited that the conceptualization of NRS may expand such that it will be considered a symptom with multiple causes and as a distinct condition. Whether or not this becomes a reality, it has become increasingly clear that even without the concomitant effects of insomnia symptoms, NRS has deleterious effects on cognitive functioning, quality of life, and may represent a vulnerability to the development of insomnia and other mental disorders.

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